BRIDGE SURFACE PAVEMENT OF THE INCHEON BRIDGE

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Abstract: *The surface pavement of bridges plays an important role of assuring safety of circulation of traffic and also protecting the deck from deformation, impact, rain water seepage and other meteorological phenomena. Since the steel deck of cable-stayed girder bridges is prone to receiving deformation impact by traffic loads and affected directly by climate influences and also the traffic control due to maintenance works that result in considerable amounts of costs, it is very important to select the paving method that will assure ample durability of the paved surface.*

1. INTRODUCTION

Marin cable-stayed section of the Incheon Bridge consists of 5 span (80m+260m+800m+260m+80m) and the total length is 1,480 m. Width of the steel deck is 31.4 m. Pavement layer for cable-stayed span consists of 'Adhesive Layer', 'Waterproofing layer', 'Guss Asphalt (thickness 4cm)', and 'Polymer Modified Asphalt (thickness 3.5 cm)'. Total amount of guss asphalt, polymer modified asphalt, and asphalt sheet is 4,230 tonf, 3,620 tonf, and 47,200 m^2 respectively.

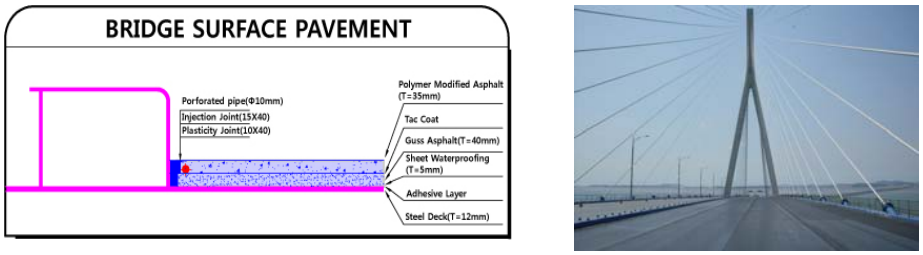

Figure 1 : Cross-section of the pavement on the cable-stayed deck

Due to possibility of high deformation by concentrated wheel loads, the surface pavement method should be selected from that of which can resist this effect. The method should allow stability in the wide range of temperature change. Dynamic Loads due to vibration, deflection, moving loads of heavy vehicles should be absorbed. Excellent corrosion preventive function of the steel deck and waterproofing capability is required. High adhesive capacity to the steel deck is required.

A construction method that will be able to tolerate the difference of the stiffness between connecting bolts and the steel plates is required. Since no detour is available during re-paving works, the life of the surface should be longer than 20 years. In order to prevent accumulation of rainwater in the pavement, drainage pipes should be installed.
For the concrete deck of the bridge, LMC (latex modified concrete) pavements were used.

2. PAVING METHOD OF STEEL DECK BRIDGE SURFACE

In the past, there were few steel deck bridges in Korea. In the 2000th, the very long steel deck bridges were started being constructed. Guss asphalt pavement was first introduced in 1997 at Jeongsan 1 bridge (Kwang-Yang city, Cheolla nam-do) and afterwards used in such bridges as Cheongdam bridge (Seoul city), Yeonjong bridge (Incheon Airport), Kayang bridge (Seoul city), and Kwang-an bridge (Busan city). The Guss asphalt technology has become a general practice in Korea and as of April 2009 in all cases of pavements were satisfactory. On the other hand, SMA pavement was applied to Seohae Bridge, the current longest cable-stayed bridge of Korea. In a few cases where epoxy water-proofing and PSMA pavements are executed, except for a few short span bridges, problems were found on bridges of span length of more than 100m.

2.1 Guss Asphalt

Guss asphalt paving is developed in Germany and has been in use for a long period of time. In most of the worlds longest bridges this Guss Pavement Method is adopted over a hundred years and is proven to be the most excellent method. Because of the fact that the void ratio of the paving material is zero, it has very high anti-corrosive and water-proofing capability. Also the aging speed is low which allows the life span of the pavement equal to or longer than 20 years.
Guss asphalt has follwong characteristics.

Water proofing character.
As a mixture of 3 petroleum asphalt and 1 natural asphalt (Trinidad Lake Asphalt) with 9% binding material, it has 0 void ratio with good fluidity thus allowing no necessity of compaction when casting. It has excellent anti corrosion and water-proofing character.

Durability
No rainwater could penetrate due to water-tightness of the material which enables to slow down the aging of the binder. There are many examples of endurance of between 20 and 30 years.

Flexibility on Bending and Resistance on Impact
As characteristics of the natural asphalt, it owns the excellent quality of the bending flexibility in response to the car load and also the resistance on impacts

Adhesiveness
Since adhering strength to the steel deck is very high (over 20 ㎏ f/㎠), there is no fear of damage due to bad adhesiveness.

2.2 Epoxy Asphalt

This method is developed in the United States. In order to obtain highly durable pavement surface, mixtures of epoxy resin is used but execution is very delicate and extreme high strength of the surface is found to be the cause to the damages of the pavement. In China, recently this method is used in some bridges but they are now switching to Guss Asphalt.

2.3 Stone Mastic Asphalt

By optimizing the aggregate graduation to minimize the plastic deformation and by increasing the binder material through the addition of natural fiber, the quality to resisting the plastic deformation and durability is increased. Using the polymer moncried asphalt as the binder it is being proved of the high quality in the steel deck surface paving. However, it seems to be too early to apply in the very long steel deck bridge surface pavement.

3. SURFACE PAVEMENTS OF INCHEON BRIDGE

3.1 Selection of Construction Method

Incheon Bridge will be 5th largest cable-stayed girder bridge in the world and also will be the longest in Korea. With a total length of 1,480 m including the adjacent spans, it represents a symbolic landmark in the country and also demonstrates to the world the bridge construction capability of the Korean construction industries.
The surface pavement is done in accordance with the requirements of the investing company (IBC) with consideration of anti-corrosiveness, water tightness and durability. Pavement method is selected from among the following combinations. After technical criterion and investigation of the past execution examples in Korea and other countries No. 4 method is selected as the most reliable solution.

① Epoxy waterproofing + PSMA Pavements (2 layers)
② MMA waterproofing + PSMA Pavements (2 layers)
③ MMA corrosion protection + sheet waterproofing + Guss + PMA
④ Adhesive layer(Anti-corrosive layer) + Sheet waterproofing + Guss + PMA

Figure 2 : Paving Constructions on the Cable-stayed span of the Incheon Bridge

3.2 Surface treatment of the Steel Deck

The surface of the steel is treated with steel grit blasting in accordance with the ASTM D 610, allowing less than 3% of residual rust.

3.3 Adhesive layer (Anti-corrosive layer)

The treatment of adhesive layer (i. e. anti-corrosion layer) is done by single liquid type using polymer modified asphalt. Two applications of commercial anti corrosion adhesive (HS Multi Coat-B) is performed to prevent corrosion of steel members and at the same time to act as primer for the asphalt sheet layer.

3.4 Asphalt Sheet

In general, there is no necessity of waterproofing layer in Guss asphalt paving. In Japan in all the long bridges are paved with Guss asphalt with no waterproofing layer provided. In the case of Incheon Bridge, in accordance with the requirements by IBC, asphalt sheet MP-RH SD which conforms to the German specification of ZTV-BEL-ST92 is used. The thickness of the sheet is 5mm . A special spreading equipment is used for better quality control.
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3.5 Guss Asphalt

The thickness of Guss asphalt pavement is 4 cm and the quality is based on the following table.

Table 1 : Specification of Guss Asphalt Binder

Item	Specified Value		Testing Method
	Petroleum Asphalt	Natural Asphalt	
Penetration(25℃) 1/10 mm	20~40	1~4	KS M 2252
Softening Point ℃	55.0~65.0	93~98	KS M 2250
Ductility(25℃) cm	Over 50	-	KS M 2254
Loss on Heating %	Under 0.3	-	KS M 2255
Tolubilityin trichloroethane %	Over 99.0	52.5~55.5	KS M 2256
Flash Point(C.O.C) ℃	Over2 60	Over 240	KS M 2253
Specific Gravity(25℃)	Over 1.0	1.38~1.42	KS M 2002

Table 2 : Aggregate Gradation of the Guss Asphalt

Sieve Size(㎜)	Standard	Composite gradation	Remark
13	100	100	
5	65~85	68.5	
2.5	45~62	53.1	
0.6	35~50	38.4	
0.3	28~42	34.6	
0.15	25~34	29.9	
0.074	20~27	24.7	

Table 3 : Calibration of Binder Content

Test Classification		Design Stqandards	Design Mix		
Binder Content %		7~10	8.2	8.4	8.6
Luer Fluidity	sec	Under 20	10.8	10.8	7.8
	Temp (℃)	240	235	241	243
Indentation Value (mm)		1~4	1.61	2.41	5.38
Dynamic Stability(60℃) Time		Over 350	550	602	-
Flailure Strain (-10℃)		Over 8×10^{-3}	-	1.7×10^{-2}	-

* Content of binder to be 8.4% and Test pieces are made using cooker.

Production and spreading of Guss Asphalt Concrete.

The production of Guss asphalt concrete is available at an ordinary asphalt concrete plant with a little modification of the facilities. In the case of Incheon Bridge the production is made at a plant located in Yeonjongdo owned by a coleany called Yeongjong Ascon Co. Ltd. The ttleerature of concrete at production was set at 190℃ -210℃ and delivery is made using Cooker to maintain heated ttleerature of between 220 C to uct C. Since no coleaction is needed, the fluidity of asphalt is very ileortant. Spreading of Guss asphalt is done by using special equipment. For formworks, magnet fixed rectangular steel pipes are used

Spreading Guss Asphalt

Before spreading the Guss asphalt is executed, Evaluation on thermal influences was made. In accordance with this study, the speed of spreading operation was set to be less than 1.0 m/min and, the width of pavement was determined as 15.20 m (= 2.8m + 3.3m + 2.8m + 3.3m + 3.0m. from lane 1 through lane

Measured from the edge of the bridge

The order of spreading execution was done; first, on lane 1 and 4, second, on lane 2 and 5, and thirdly, on lane 5. Longitudinally, the paving started from the lower point to higher location, in this case, started from the airport side.

For the execution, 2 units of special spreader machines, and 10 cookers are employed. A daily spreading of between 100 tonf to 140 tonf of asphalt concrete were made with no difficulties.

Measurement and Quality Control on the Guss Asphalt

① In accordance with the plan set at Evaluation on thermal influences, gauges for measuring temperature, deformation and strain were placed and the readings are constantly monitored. There were no records that were exceeding the allowed limits.

② On the quality control for the Guss asphalt, Luer fluidity tests and penetration tests are made twice a day meaning more strict quality control performances compared with ordinary practice performed on other bridges.

Because the Guss paving is done with special equipment with very hot material (220℃~240℃) particular attention should paid on the following.

- Heated temperature of the aggregate
- Heating of the Cooker
- Blistering phenomena
- Evaluation of heat influence on steel bridge
- Order of paving operation and speed of execution
- Vehicle circulation during execution

Figure 3 : Paving of Guss Asphalt (left) and PMA (center). Slab Drain (right)

3.6 Tac Coat

For Tac Coat material, in order to improve adhesive property of Guss asphalt surface polymer modified asphalt rubber added asphalt emulsion (commercial name: SP COAT) is used. Curing of at least 24 hours was required.

3.7 PMA(Wearing Course)

In consideration of climate condition of Korea, the polymer modified asphalt is used for upper layer of Guss asphalt. In Germany, Guss asphalt is being used but in Japan where climate is similar to Korea they are using always PMA. The thickness of the surface layer is decided to be 3.5cm and gradation of asphalt density is specified 13mm.

Table 4 : Specification of PMA Binder (PG: 76-22)

Test Classification	Value	Testing Method
Flashing Point	Over 230℃	KS M 2010
Viscosity @135℃	3,000 cp	KS F 2392
G*sinδ@10 rad/sec	Over 1.0 kPa @76℃	KS F 2393
Short term declining		
G*sinδ@10 rad/sec	Over 2.2 kPa @76℃	KS F 2393
Long term declining		
G*sinδ@10 rad/sec	Under 5.0 kPa @31℃	KS F 2393
Creep Stiffness @-12℃	Under 300 MPa	KS F 2390
m-value @-12℃	Over 0.3	KS F 2390

Table 5 : Specification for Polymer Modified Asphalt Paving Mixture

Item		Value
Marshall Test	Void Ratio %	3 ~ 5
	Saturatio %	78 ~ 85
	Stability kg	1,000
	Flow rate 1/10 mm	20 ~ 40
	Retained Stability %	80
Wheel tracking test(60℃, 6.4kg/cm^2) Time/mm		1,500

3.8 Joints

Joints consist of upper joints and lower joints. Lower joints are of the tape type and are installed before the paving operation between structure and the asphalt while upper joints are formed with temporary plywood pieces during the paving operation and later replaced with the melted joint material which is injected in place

Table 6 : Specification for Joint Material

Item	Value	Testing Method
Penetration (mm)	Under 6	JIS 314
Flow (mm)	Under 5	〃
Elongation (mm)	Over 3	〃

3.9 Slab Drain

Since the drainage of internally and externally accumulated water is closely related to the durability of pavement, it should be treated with extreme care. Especially because the technology of internal water drainage method is only recently developed, there is a tendency of neglecting this but this item should be carried out without fail. In the case of Inchon Bridge, in the upper polymer modified asphalt layer, polyester net type 10mm perforated pipes are installed. In the Guss Asphalt none is provided because the asphalt itself is watertight.

Table 7 : Specification for Perforated Drainage Pipes

Item	Value	Testing Method
Pipe stiffness deflection level 5%	Over 10kgf/cm^2	ASTM D 2412:2002
Thermal resistauce	No didfiguration at 240℃ for 30Min	

4. METHOD OF PAVEMENT ON THE CONCRETE DECK BRIDGE

4.1 Latex Modified Concrete Pavement

The Latex Modified Concrete (LMC) pavements were applied into the bridge with concrete decks. It is a significantly performed concrete which evenly mixture with the water and latex included with decentralized stillene/buthadiene polymer. The way of a Method of LMC pavement that around 5 cm depth paving and finishing right after cut the bridge deck surface approximately 3 mm to erase the remains or the weakness parts.

Water (50%) + S/B Polymer (50%) = Latex

Latex + Concrete = LMC

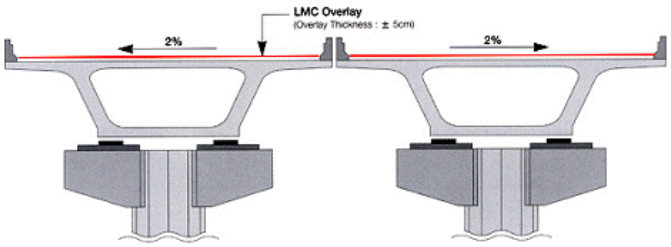
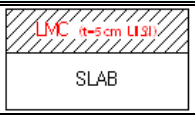
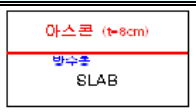


Figure 4 : Composition of LMC

Special featuring of the LMC :
- Increased a fluidity and excellent operation of concrete by flow the interface of Latex.
- Improved the separate of material by viscosity of Latex nature.
- Increased an adhesive power of new and existed concrete by the adhesive performance of Latex.
- Advanced persistence and repressed outbreak a crevice by increased warping & tensioning.
- The growth watertight and the best waterproof by fill of solidity powder of Latex.
- Continuously maintenance of the flatness in the line of duty because of no variations of paved surface.
- The greatest reduced maintenance fee and transportation providing their flights.
- Promoted life of duty of concrete deck bridge.

Table 8 : Comparison with existed method

		LMC METHOD	ASPHALT METHOD
Structure			
Special Feature	**Strength**	· Warp strength 60-100 ㎏/㎠	
	Crevice	· No crevice, big resistance	· Crack of turtle neck, Line crack, all directions crack
	Water	· Very low penetration by Latex	· Big penetration by crack and gap between the materials
	Adhesion	· Adhesive power 16-23 ㎏/㎠	· Small profits by rain and water
	Freezing	· against freezing calculation is over than 90%	· Damaged by freezing cause of penetrated water
	Variance	· compressed power 300-360 ㎏/㎠, no variations and continuous maintenance	· early degradation the flatness by the variance
	Operate weight	· resist to wheel weight and prevented the steel bar by increased thickness of coating	· paved asphalt becomes an operate weight onto the deck
	Life time	· Reduced the damage against the salt, frost, neutral ⇒Promoted performance of Concrete Deck ⇒Extend the duty life time	· Injury by variable reason ⇒early degraded concrete deck ⇒Reduction the duty life time
Maintenance		· Best resistance to variance → first flatness continuous maintenance · Best property of material (warping/tensioning/adhesion power/watertight etc.) ⇒ Repression the cracking outbound ⇒ Suppression the damage from the salt, frost, neutral ⇒Promotion bridge durability ⇒Decrease proportion rate of maintenance ⇒Reduce Maintenance fee ⇒Easy transport condition	· early degradation the flatness by transformable pavement ⇒Required repetition maintenance ⇒Extra maintenance fee ⇒Transportation trouble ⇒Waterproofing system damage by cut the road for maintenance ⇒Deterioration bridge durability
Expectation of life time		23 years	7 years

4.2 Method of Construction and Procedure

Construction procedure of LMC pavement is shown in Figure 5.

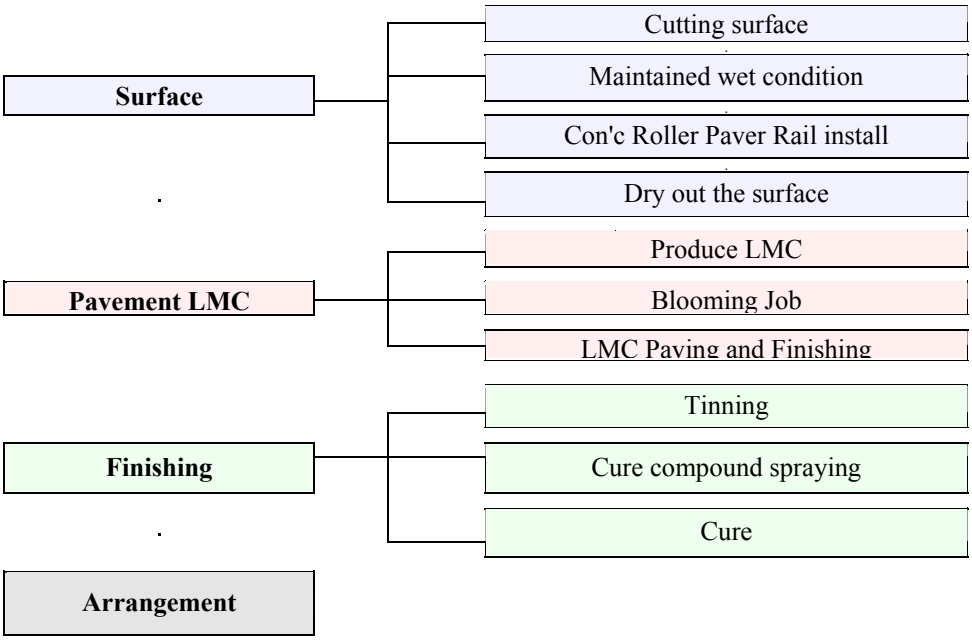
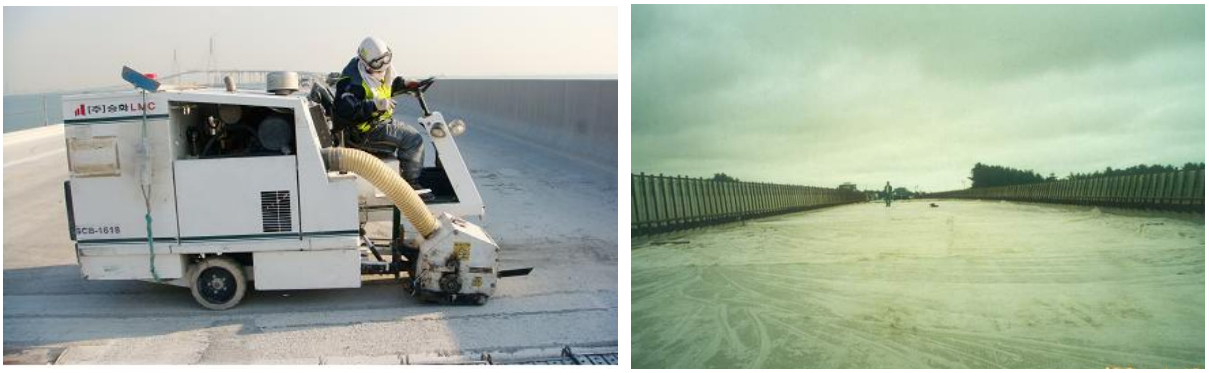


Figure 5 : LMC pavement procedure

Cutting

This is a job proceed with significantly impact of adhesive power of LMC. The proceeding executed such as the cutting to make a prominence and depression on the concrete surface for adhesion, the shot-blasting to erase the remains on the surface, the grinding with human-power to make complete impossible side to reach the machine.



Figuer 6 : Cutting Job (left) and Maintenance to Damping Condition (right)

Maintenance to damping condition

This is proceeding for maintenance to damping condition to avoid water absorption by existed concrete surface with dry-out after cutting job.

Install the screed rail and screed chair

Install the screed guard and chair on the protection wall and guard rail to make through way for Concrete Roller Paver, Tinning & Curing Machine, Work-Bridge etc. The Screed rail required solid installation to avoid variation and interval a space of approximately 100cm. The screed rail is very important to make flatness a surface, it is necessary to measurement before install it.

(a) Rest on the wall type (b) Support type

Figuer 7 : Screed Rail and Chair

Maintenance damping condition of existed surface

Required damping on the existed surface before LMC as below photo. Pour the water use with high pressure water hose and cover it with vinyl cover the day before. The vinyl covers take-on and off is depending on the weather condition.

Figure 8 : Surface Cleaning

Figure 9 : Vinyl covering

Produce the LMC

Produce the LMC with Mobile Mixer like as below photo.

Figure 10: Produce the LMC

Figure 11 : Blooming Job

Blooming Job

To fill up on the surface which is already finish the cut job, blooming job with LMC mortar and finish the job with man-power to complete the Center wall and protection wall.

Pavement of LMC

Finish the Job with Concrete Roller Paver. Also, needs a man-power side where is not reachable the Concrete Roller Paver. Figure 13 shows a tinning job to avoid car slipping on the road.

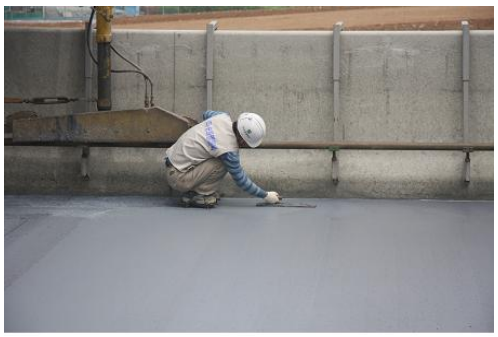


Figure 12 : Final job with Roller and man-power

Figure 13 : Tining Job

Curing

After Tinning, spraying the cure compound and water spraying to avoid cracking the surface cause of water vaporization. At least 15 days require to open the transportation passage should control for good quality management.

Figure 14 : Concrete Curing

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